SEDIMENT MONITORING & MODELING PROJECT
SMITH BRANCH OF ROUBIDOUX CREEK
FORT LEONARD WOOD, MISSOURI

Marvis Meyer - Natural Resources Branch - Ft. Leonard Wood, MO.
Jeff Lamb - Natural Resources Conservation Service - Houston, MO.
Paul Albertson - US Army Waterways Experiment Station, Vicksburg, MS

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ABSTRACT

One of Fort Leonard Wood’s missions is the training of combat engineers and soldiers. Certain training activities can increase the rate of soil erosion and sediment delivery downstream. Clean Water laws limit the amount of sediment that can be discharged into the waters of the state. Determining the amount of sediment in storm water is a very technical and uncertain process. An interagency team has been assembled at Ft. Leonard Wood to begin a sediment monitoring study within Smith Branch of Roubidoux Creek. The objectives of the study are to estimate the sediment delivery at 3 different points within Smith Branch watershed by measuring rainfall, discharge rates, and sediment loads during certain storm events. Sediment load information can then be used to calibrate various computer watershed models which can be used to predict sediment yields in other areas of the fort. It can also be used to determine if compliance issues are being met as related to water quality and what conservation practices might be needed to mitigate non-compliance. This paper will discuss the methods used in monitoring and evaluating this study which has the potential to assist the personnel in managing the natural resources of the installation.

INTRODUCTION

Fort Leonard Wood is a United States Army Military Reservation located on the Ozark Plateau in south central Missouri and comprises about 25,200 hectares (63,000 acres). Army ownership and training was established in 1941 The U.S. Army Engineering Center based at Fort Leonard Wood, trains enlisted and officer personnel in basic combat, military engineering, and motor vehicle operations.

Recently, the mission expanded to include other branches of the Armed Services. In 1996 the Interservice Training Review Organization (ITRO) program was instituted and entails Motor Transport Operator Training and Heavy Equipment Engineer Operator Training of Army, Air Force, Navy, and Marine Corps personnel. Beginning in 1999 the mission will expand to include the army chemical defense and military police schools and will be collectively called the Maneuver Support Center (MANSCEN) for the Army. The Environmental Impact Statement (EIS) associated with this expansion stated that "the activities will increase erosion, soil loss, and sedimentation" (U.S. Army 1996). However, the EIS only states the problem qualitatively. Commanders and resource managers need to understand the cause and effects in quantitative terms. The research contained in this paper examines the problem using quantitative geomorphic procedures.

PROBLEM

The Deputy Chief of Staff for Operations and Plans, Macia (1995), emphasized the need to "sustain one of the Army's most valuable resources, its lands." He went on to define a greater challenge, "to predict more objectively, the impacts and effects on our lands." Certain training activities as well as construction activities can increase the rate of soil erosion and sediment delivery downstream. Clean Water laws limit the amount of sediment that can be discharged into the waters of the state to protect the water quality for various uses by humans and wildlife.

Construction and training activities at the fort occur over large tracts of land resulting in the potential for high rates of soil erosion and sediment transport. One of the most extensive training areas at the fort is Normandy Training Area (TA-244). Here, enlisted troops are trained to operate and maintain bulldozers, motor graders, earthmoving scrapers, cranes, backhoes, dump trucks, fork lifts, earth compacting equipment, loaders, compressors, drills, water distribution equipment, and combat engineer tracked vehicles.

Specific to the Smith Branch watershed are concerns such as poor fish populations and growth. For example in Bloodland Lake which is a 40 acre recreation lake located on Ft. Leonard Wood and Shanghai Spring on Big Piney River are due in part to high turbidity levels caused by excessive soil erosion from Ft. Leonard Wood construction and training activities. The short duration, high-intensity runoff events result in substantial soil erosion and sediment transport to area streams and springs. Water quality concerns voiced by a local fishing group brought the problem to the forefront. Determining the amount of sediment in stormwater is a very technical and uncertain procedure.

PROJECT OBJECTIVES

In 1996 a study of Smith Branch of Roubidoux Creek was conceived to determine the amount of sediment being moved downstream as a result of various training and construction activities. An interagency team with specialists from various disciplines was assembled to study the problem.

The overall resource management objectives of this project are to reduce soil erosion and sediment delivery coming from Fort Leonard Wood construction and training activities to area streams, lakes and springs which will improve the overall water quality of the area.

The monitoring objectives are to determine the water quality of Smith Branch and Shanghai Spring by measuring rainfall, discharge rates, and sediment loads. This information can then be used to determine if the fort is in compliance with state water quality standards and what conservation practices might need to be implemented to correct the problem. Sediment load information can be used to calibrate various computer watershed models which can be used to predict sediment yields in other areas of the fort. Monitoring of best management practices (BMP) are being conducted but their true effectiveness remains uncertain.

STUDY SETTING

LOCATION AND SIZE

Smith Branch is a tributary of Roubidoux Creek. The watershed is owned totally by the U.S. Army and is located near the center of the installation (Figure 1). The study area encompasses approximately 3600 acres of the upper watershed. The topography of Smith Branch is characterized by nearly level to steep slopes. A narrow flood plain occurs on the area below Bloodland Lake. The elevation ranges from 1286 feet to 996 feet above mean sea level. Slopes ranging from 2 to 25 % characterize the relief of the study area. The extreme upper watershed of Smith Branch flows into Bloodland Lake while the middle portion of the watershed is known to be a losing stream and contributes to the flow of Shanghai Spring and other springs on the Big Piney River. It flows in a northerly direction until it reaches Roubidoux Creek and then to the Gasconade River and ultimately to the Missouri River.

Figure 1. Location Map of Smith Branch Study Area within Fort Leonard Wood

GEOLOGY

The geology of this watershed is primarily in the Jefferson City and Roubidoux formations, which were formed the Ordovician time periods. The Jefferson City Dolomite is interbedded with chert and has thin layers of sandstone and shale. This formation underlies the broad upland divides. A light brown or brown cherty silty clay forms as the dolomite weathers. The Roubidoux formation is a brown to brownish red, sandy dolomite, cherty dolomite, and sandstone. Weathering of the bedrock results in residual soil laden with chert and sandstone fragments of various sizes intermixed with a reddish silty clay. Because of the effects of the weathering, sinkholes have developed in this formation, which lead to the underground aquifer that recharges many of the area springs. Generally, the surficial material is 5 to 10 feet thick. It may be more than 35 feet thick, however, in areas of strongly weathered bedrock. A layer of loess covers the broad upland divides to a depth of 1 to 3 feet. Alluvium is deposited in the floodplain of Smith Branch.

SOILS

There are 3 different soil associations mapped within Smith Branch (Wolf 1989). The broad ridges are mapped in a Lebanon-Plato association which are deep, gently sloping and moderately sloping, moderately well drained and somewhat poorly drained, silty soils on uplands. The Viraton-Clarksville-Doniphan association are deep, gently sloping to steep, moderately well drained to somewhat excessively drained, silty and very cherty soils on uplands. The Clarksville-Gepp association is deep, moderately steep to very steep, somewhat excessively drained and well-drained, very cherty, cherty, and stony soils on upland areas.

CLIMATE

The climate is humid temperate continental characterized with warm summers and mild winters. The average temperature is 56 degrees. The annual precipitation ranges from 24 inches to 60 inches. Most precipitation is in the form of rainfall with snowfall of only a few inches. The average annual precipitation is about 40 inches. The average growing season is about 156 days (Missouri Crop and Livestock Reporting Service, 1980).

PREVIOUS SOIL-LOSS STUDIES

Trumbull et al. (1989) studied the impacts of military camping at FLW. They inferred 28 to 61 cm of soil loss over period of 20 to 40 years. Closer examination of the data revealed that military bivouacking could have occurred for a period 34 to 48 years. Accepting their assumptions and dividing by period of time results in rates of soil loss of a minimum 0.58 cm/yr, a maximum of 1.79 cm and an average of 1.09 cm/yr. Visiting the training areas studied by Trumbull et al (1989) revealed some areas (e.g.10 m x 10 m) appeared to have lost of about 0.5 m but the entire acreage had not been denuded to that extent. Therefore, the minimum rate of 58cm/ century rate is more likely. Using the lower rate translates to 37 Ton/Acre/Year of erosion caused by bivouacking. This figure is almost twice the 20 Ton/Acre/Year value reported by Proffitt (1994). He summarized the data for bivouack sites and reported rates from 2 to 20 Tons/Acre/Year. Thus, there remains uncertainty of the effects of training on the landscape.

Lamb and Meyer (1995) applied USLE to estimated soil loss in Normandy Training Area 244 (TA 244). They calculated a rate of 23 Tons/Acre/Year without erosion control. The equation indicated that by adding erosion controls, soil loss was reduced by a half. There remains an uncertainty between monitored values and estimates from modeling.

A 1993 sediment study of a detention pond revealed 91 acre-feet of sediment accumulated over approximately 30 years. After allowing for a trapping efficiency of 30 % and sediment delivery rate of 20 % (ASCE 1977), it was calculated that the soil loss from training amounted to 28 Tons /Acre/Year.

SEDIMENT MONITORING

Method

Rainfall measurements, stream discharge and sediment samples were collected in the Smith Branch Basin Study Area in an attempt to quantify the effectiveness of BMP erosion control measures. Three automatic water samples installed to monitor the effects of training in the basin due to training activities. These samplers were monitored by the USGS WRD to record training impacts to the Smith Branch Watershed.

The design of the sediment monitoring system followed a nested approach (NCRS 1997). The nested design implemented for this project with 3 flow meters and water samplers installed at strategic points within the watershed. Figure 2 shows Smith 1 nested into Smith 2 and both Smith 1 and 2 nested in Smith 3.

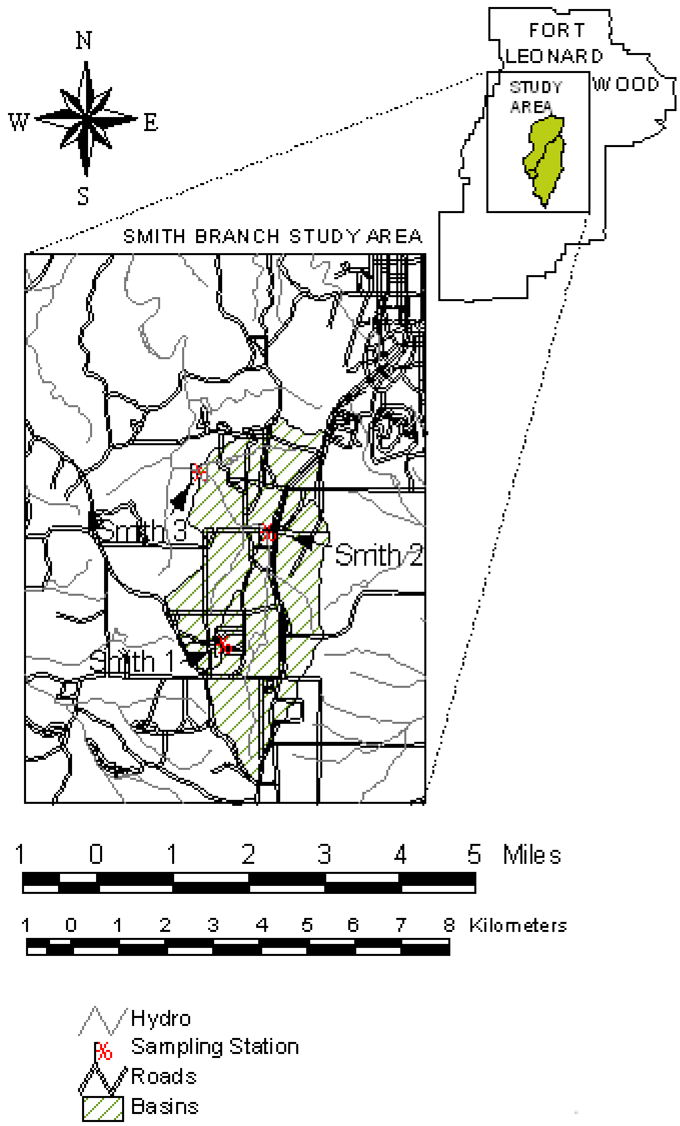

Figure 2. Location of Sampling Site with the Smith Branch Basin Study Area

SMITH 1 - This site is above Bloodland Lake and located within Training Area 236. The monitor has been placed below a 4.2 ft. diameter road culvert to monitor flow rates. It has been established to monitor sediment loads entering into the lake from one portion of the watershed on the west side. The sediment load is coming from the gravel roads within TA 236, which is a heavy-truck driver training course and from another gravel access road on the west. There is also gully erosion taking place in the ditches next to these roads. These areas are planned to have conservation treatment applied to reduce the erosion sometime in the future. There are approximately 2 miles of gravel roads within this watershed of 95 acres consisting of between 10 and 12 acres.

SMITH 2 - This site is located below Bloodland Lake. The monitor has been placed below a 7.6 ft diameter road culvert. It has been established to determine the sediment load and water quality before being influenced by Normandy Training Area (TA 244). There are uncontrolled sediment sources below Bloodland Lake that may have an influence on the sediment load measured at this point. These include gravel roads and shooting ranges that have excessive erosion occurring in some areas. The watershed area measured at this point is 1956 acres.

SMITH 3 - This site is located below Sediment Pond #4 which is the largest sediment pond located on Ft. Leonard Wood and below Normandy Training Area (TA 244). Normandy is the heavy equipment training area for the combined armed forces. The monitor has been placed below a 36 inch diameter concrete pipe that is used as a principal spillway for Sediment Pond #4. This station has been established to determine the effects Normandy has on the sediment load and water quality of Smith Branch before it enters Roubidoux Creek located 5 miles downstream. Significant sediment loads are generated from Normandy due to the type of training. Although there has been some major conservation work done within Normandy during the last 4 years to reduce the amount of soil erosion and sedimentation occurring downstream it is not known to what level this has occurred. There are other sediment sources including gravel roads outside of Normandy that are contributing to the sediment load. The watershed area at this point is measured at 3603 acres.

Table 1 provides information on the characteristic of the sub-basins.

Table 1. Smith Branch Basin Sediment Monitoring Information And Estimates

Basin , Name, Area, And Description Of Land-Use Activity And Conservation Practices	Date of Rain Event	Rainfall Amount	Runoff Amount	Sediment Load	Ratio Estimated Annual Load	Graphic Estimated Annual Load
	1997	Inches	Inches	T/A/day	T/A/yr	T/A/yr
Smith 1 = 95 Acres Of Heavy Truck Training On Unsurfaced Roads	May 30-31	1.44	0.61	0.02		
	Jun 13-14	1.85	0.63	0.04		
	Aug 19-*	2.10	0.30	0.01		
	Oct 25-26	1.26	0.18	0.01		

	Totals	6.65	1.73	0.07	0.52	0.633
Smith 2 = 1956 Acres With A Mixture Of Roads, And Ranges With Sediment Ponds	May 30-31	1.38	0.37	0.00		
	Jun 13-14	2.46	0.63	0.02		
	Aug 19-*	2.27	0.21	0.00		
	Oct 25-26	1.32	.06	0.00		
	Totals	7.43	1.28	0.02	0.20	0.290
Smith3 = 3600 Acres Of Heavy Equipment Training With Sediment Ponds	May 30-31	1.20	0.28	0.01		
	Jun 13-14	2.26	0.86	0.05		
	Aug 19-*	1.99	0.18	0.01		
	Oct 25-26	1.44	0.05	0.00		
	Totals	6.89	1.37	0.07	0.59	0.659

The sediment was collected following USGS protocol as described in *Field methods for measurement of fluvial sediments* (Guy and Norman 1973). Southard (1997) used the equal-transit-rate (ETR) method to determine the sediment concentration of the flow. The ETR method yielded a gross sample proportional to the total stream flow. The computations of the fluvial sediment discharge followed procedures outlined by Porterfield (1972).

Monitoring Results

Steamflow discharge and sediment data was analyzed and complied by the USGS (Southard1998). Figure 3 presents an example of data from one site for two rainfall events. Data from four events at the three sites were evaluated and an annual sediment load was estimated. An assumption was made which related the storm runoff to the annual effective runoff. The reported average annual runoff of the study area vicinity is 12 inches (Waite and Skelton 1986). Measured sediment loads were multiplied by the event/annual-runoff ratio resulting in estimated annual loads. The results amount to sediment load equivalent values ranging from 0.2 to 0.6 Tons/Acre/Year. Calculations are presented in Albertson (1998.) The results are summarized in Table 1.

An alternative method was a graphical solution using linear trend lines . The results were 0.63, 0.29, and 0.66 Tons/Acre/Year for Smith 1, 2, and 3, respectively. The linear trend lines explained the relationship well with coefficients of determination (R^2) values of 0.82, 0.82, and 0.97.

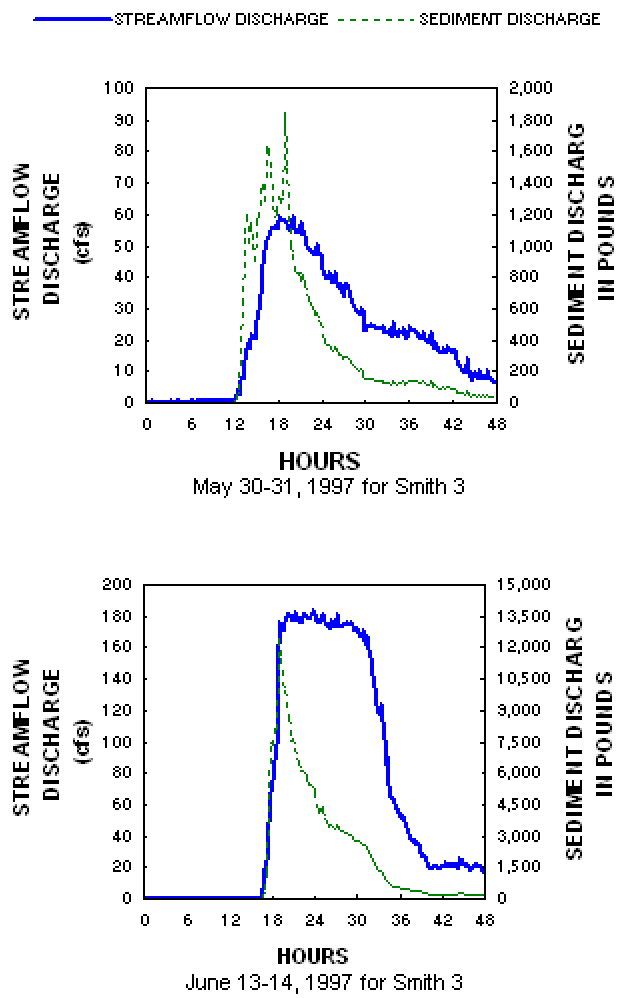

Figure 3. Relationship of Steamflow and Sediment Load for Two Events, May 30-31 and June 13 - 14, 1997 Measured At Smith 3 Station

SOIL-LOSS MODELING

PROCEDURE

Actual measured data of sediment derived from selected watershed points (Southard 1998) were collected during four events for one year. In order to investigate if conservation practices were reducing soil-loss, simulations were needed to estimate soil loss further back into the past. Soil-loss models can back-calculate the effects of land-use activities over the previous decades and centuries. However, what model to use was a matter of debate because each approach had advantages and limitations.

Most early soil-loss models were parametric, i.e., based on factors that control soil loss. The most widely used model has been the Universal Soil Loss Equation (USLE). Despite the widespread application of USLE, researchers (e.g., Morgan 1986) have found limitations in predicting erosion rates. More recently, Carden-Jessen (1998) reported that USLE was unsuccessfully in predicting soil erosion due to off-road vehicles on US Forest service roads. Sun and McNulty (1997) showed application of USLE to forest landscapes. Proffitt's (1994) results indicated that USLE does not adequately model military lands. Increased recognition has led to a movement to replace the USLE equation (Morgan 1995). Jones et al. (1996) suggested using the revised-USLE (RUSLE). Like its forerunner, RUSLE does not estimate the amount of soil leaving a site but it only estimates soil movements. Despite the promise of new and better models, and the criticism of empirical model such as USLE and RUSLE, a recent review of soil-loss models available to the US Army still recommended RUSLE (USACE 1997). Thus, for this research, simulations were made using only the RUSLE model. The modeling exercises were intended to simulate the effects of changing land use on soil loss. Modeling of the FLW landscape used RUSLE for comparison with sediment studies (Southard 1998) and to produce results acceptable to the natural resource community.

Revised Universal Soil Loss Equation (RUSLE) is same as USLE only the methods to determine the variables have been revised. The procedure used "ArcView spatial analyst" to estimate the soil-loss distribution across the basin through time. The Revised Universal Soil Loss equation is:

$$A = R \times K \times (LS) \times C \times P$$

Where –

A = estimated annual soil loss (Tons /Acre/Year)

R = rainfall factor of energy and intensity

K = soil erodibility

LS = topographic factor; slope length (L) and slope steepness (S)

C = crop management or cover class

P = Practice or conservation class

The following discussion describes how each variable was selected. The R factor of 225 for rainfall energy was obtained from the Field Office Technical Guide (NRCS 1997). During these simulations, R was held constant at 225 to represent average annual rainfall conditions in Pulaski County. The soil erodibility (K), the length-steepness (LS) values for each soil series are presented in Table 2.

Table 2. Selected Soils of Smith Branch, Pulaski Co., Missouri								
MAP UNIT	SERIES NAME	AVE SLOPE	AVE SL LNTH	GRASS FOREST AVE LS	CONSTR SITES AVE LS	CROP LAND AVE LS	RUSLE ADJK VALUE	T VALUE
12A	Cedargap	2	113	0.26	0.29	0.27	0.2	5
13A	Cedargap	2	113	0.26	0.29	0.27	0.28	5
16D	Clarksville	12	155	1.99	2.57	2.27	0.24	3
16F	Clarksville	25	155	5.1	6.46	5.8	0.24	3
20C	Doniphan	6	114	0.77	0.88	0.82	0.24	3
32C	Viraton	6	223	0.93	1.33	1.11	0.37	4
35B	Lebanon	4	175	0.56	0.74	0.64	0.37	4
35C	Lebanon	7	175	1.07	1.39	1.19	0.37	4
39D	Ocie	12	203	2.21	3.08	2.63	0.28	3
41B	Plato	4	150	0.54	0.68	0.6	0.37	4
42C	Gunlock	6	140	0.81	1	0.9	0.32	4
99	Udorthent	4	175	0.73	0.74	0.64	0.28	5

The other two factors C and P are the variables that land mangers have some control over. The C-factors are subjective but were selected from a review of literature (Jacobson and Prime 1994, NRCS 1997) and consultation with local soil conservationists. Land cover for circa 1800 was derived from pre-settlement vegetation GIS coverage (Jones 1995). The C-factor was assigned based on land-cover. The pre-settlement land cover from Jones (1995) portrayed essentially two land covers, one was the post oak flat which was assign a C = 0.003 and the second was thinner slope woods which was assigned a C = 0.05. The 1980 simulation used land-cover derived from the USGS (1990). Land cover was differentiated by using the USGS 1990 land-use/ land cover classification. The land cover based on 1:250,000 scale data lumped the landscape too much for meaningful results.

In order to derive more detailed and distributed land cover an automated aerial-photographic technique was employed (Albertson 1998). Certain vintages, e.g., 1938, 1955, 1976, and 1997 were selected because of availability and to represent changes in land use. The process to transform the aerial photos to useable digital data was tedious and time consuming. The photos were scanned, geo-referenced, and mosaiced for later comparison and processing. Remote Sensing software was used to perform supervised classification. The scenes were classified into 4 classes and then C-factors were assigned during a reclassification procedure according accepted values. Table 4 shows the classes and C-factors used during each RUSLE run.

Table 3. Land Cover C-Factor Classification

Class	Land Cover	C-Factor
1	Bare Ground; 0 to 10% cover	1.0
2	10 to 50 % cover	0.18
3	50 to 90 % cover	0.05
4	Woodland; 90 to 100 % cover	0.003

The RUSLE model was run with R, LS, and K held constant for each time simulation. Once the C factors were set for each of the land-cover classes for the 1997 RUSLE run (Figure 4) they were held constant for the subsequent 1976, 1955, and 1938 simulations. The P-factor was adjusted to reflect the degree of stewardship in each time interval. The P-factor is usually 1.0 but if soil conservation practices are installed then P-factor can be less than 1.0 (Hausenbuilder 1985). The 1997 RUSLE results were validated to reflect the 1997 sediment data and physical reason. ASCE (1977) suggested a basin of this size would have a sediment delivery ratio of about 20 %. Therefore, a soil loss of 0.6/0.2 to 0.66/0.2 would be expected to about 3 to 3.3 Tons/Acre/Year. The basin also contained sediment ponds that will reduce sediment delivery. The recent (1997) aerial photos were examined to estimate the pond size/ basin size ratio. Consulting the ASCE (1977) sediment pond trapping curves suggested that the ponds would trap about 30 % in Smith Branch Basin. Therefore, the 3 to 3.3 Tons/Acre/Year translates to 4.3 to 4.7 Tons/Acre/Year. The 1997 RUSLE model was run varying P between 0.1 and 0.9 as recommended by NRCS (1997). When the P-factor of 0.5 was used the model produced a mean soil-loss over Smith Basin of 4.59 Tons/Acre/Year. The RUSLE results were then considered reasonable because the input used accepted C-factors and the mean soil-loss was within the range of soil-loss estimated from the sediment sampling (4.3 to 4.7 Tons/Acre/Year). The P-factor for the 1976 simulation was change to 0.75. The higher P-factor was used to reflect less soil conservation practice. The rational was based on examination of 1976 aerial photos, which revealed that the major sediment pond, Bloodland Lake, was not built yet. Following similar rational, the P-factor of 1.0 was used for the 1955 and 1938 simulation to reflect the level of soil conservation at those times.

Results

The RUSLE model runs were conducted to simulate the effect of changing land use and land cover on soil loss. The selected simulations corresponded to time periods when land cover could be assumed, for example, 1800 for pre settlement conditions. Land cover was also estimated from aerial photographs, e.g., 1938 for pre-Fort conditions, 1955 for Post WWII and Korea War conditions, 1976 for post –Vietnam and pre-conservation, and 1997 for present conditions with stewardship level conservation.

Table 4 presents the results of the RUSLE simulations. Figure 5 presents the results as a graph of soil loss verses time. Examining the mean values on Figure 5 and in Table 4 reveals an increase in soil loss during the first 100 years of settlement. Soil loss continued to increase until conservation practices were implemented in the 1970’s and continued through the present.

Table 4. RUSLE Soil-Loss Estimates in Tons/Acre/Year for Selected Dates

Year	1800	1938	1955	1976	1997
Mean	0.24	8.40	11.90	6.70	4.57
Standard Deviation	0.17	17.97	18.40	16.32	9.84

These analyses temporally, indicated the general sediment yield trends over time. GIS analysis with ArcView portrays (Figure 4) the specific areas of spatial change. The simulations indicated that land-use activities induced high soil loss through the first half 1900’s until conservation practices became implemented in the 1970’s.

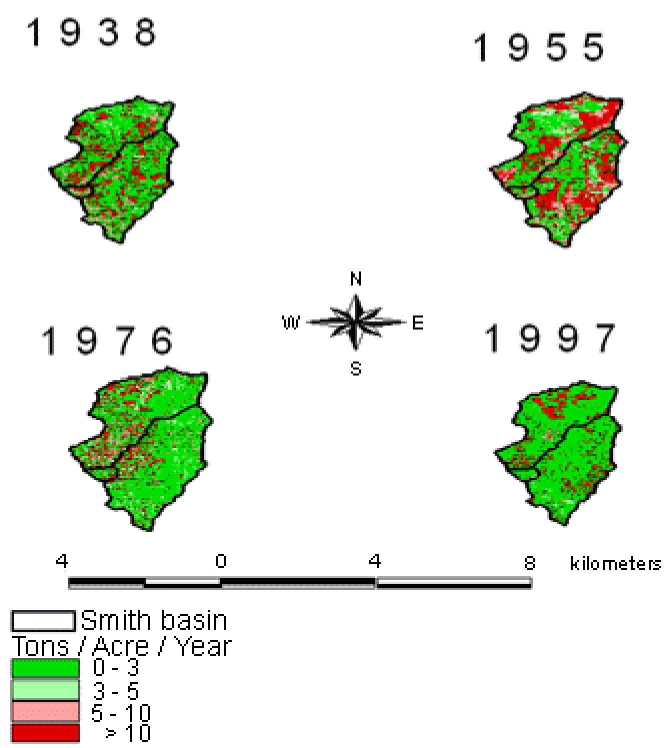

Figure 4. RUSLE Soil-Loss Simulations for 1938, 1955, 1976, and 1997

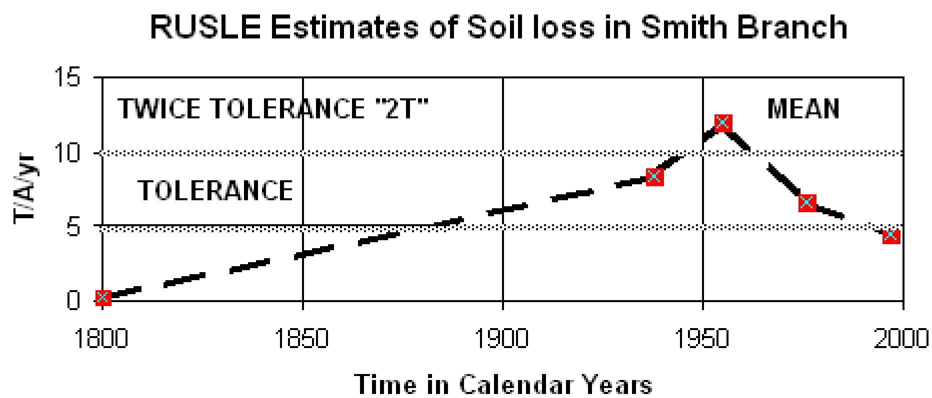

Figure 5. RUSLE Soil Loss Results through Historic Times

SIGNIFICANCE

The following examples compare the simulated soil-loss estimates to soil-loss values associated with cited land-use activities to place the results in a broader context. The ASCE (1977) manual suggested that 0.3 Tons/Acre/Year is a normal geological rate. Simulation for the pre-settlement soil-loss (Table 5) resulted in a mean of 0.24 Tons/Acre/Year, which is similar to the 0.3 Tons/Acre/Year cited by ASCE. Therefore, the RUSLE results for pre-settlement conditions were reasonable. The sustainable or acceptable soil-loss rate is known as the soil loss tolerance or "T"-factor. NRCS 1997 reported T-factors of 3 to 5 Tons/Acre/Year for the soils on site. The RUSLE results were presented in Figure 4 in Tons/Acre/Year categories of 1) 0-3 below T; 2) 3-5 within T; 3) 5-10 which is "Twice T"; and 4) greater than10 or beyond 2T.

Reported erosion rates (ASCE 1977) during urban construction were recorded as 10 to 50 Tons/Acre/Year. Both active mining and military heavy equipment training, which equates to ongoing construction, have the potential to increase erosion two to three orders of magnitude (ASCE 1977). Simulation of soil-loss in the 1938,1955, 1976, and 1997 (Figure 4) show "hot spots" with soil loss greater than 10 Tons/Acre/Year.

Figure 6 presents the RUSLE results as percentage of the study area basin in the four classes for the four time periods. Class 1 below Tolerance (<T; 0 to 3 T/A/yr) showed an increase in time except for the 1955 time step. Class 2 at Tolerance (within T; 3 to 5 T/A/yr) increased in 1955 and 1976 to about 10 % and then decreased. Class 3, Twice Tolerance (2T; 5 to 10 T/A/yr) showed a decrease after the peak in 1955. Class 4, beyond twice tolerance (>2T; 10 to 70 T/A/yr) increased from 1938 to 1955 and then decreased.

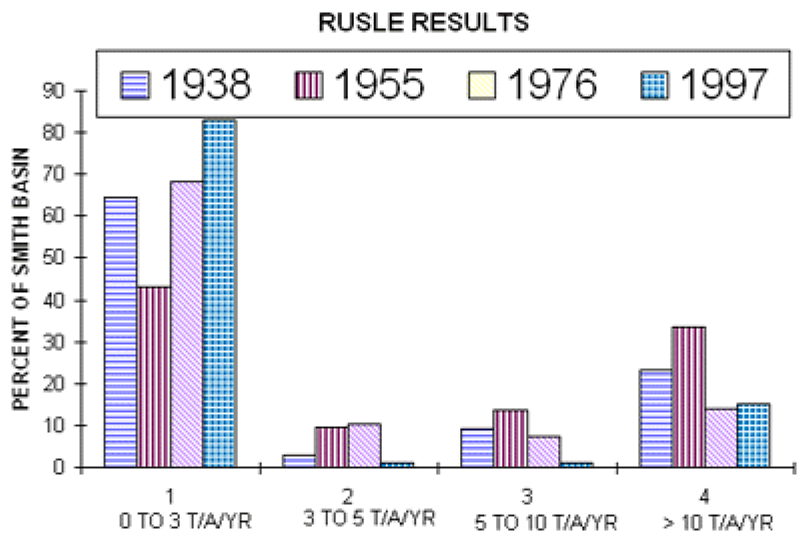

Figure 6. RUSLE Results, percentage of land in Smith Basin in soil-loss classes

Collectively, the bar chart (Figure 6) revealed a landscape healing from past land-use stresses but that still has some "hot spots" that exceed the suggested soil-loss tolerance. Present conditions (1997) are that most of the land is either below tolerance or beyond 2T. The analysis (as shown in Figure 6) reflects conservation and concentrated land use with containment. Thus, from a military planner's point of view the land is hot or it is not.

After considering the available information, estimated impacts associated with Army training resulted in the following soil-loss increases:

a. 30 to 40 times increase from pre-settlement;
b. an initial increase over 1930s agriculture but
c. less than or equal to the pre-military soil after soil conservation implementation.

The 1997 RUSLE results showed mean soil-loss within tolerance. Obviously, present land use generates more soil loss than pre-settlement conditions but present soil-loss estimates are less than during pre-military circumstances.

STUDY ASSUMPTIONS AND LIMITATIONS

RUSLE was selected because it is an accepted analytical tool for the engineering and natural resources community. However, it is an empirical equation derived from agricultural experiments and refined by experiences. Collectively, all numerical analyses have assumptions. At best, the quantitative methods only yielded qualitative results.

The RUSLE simulations were simplified by several assumptions. For example, the R factor was held constant from 1938 to 1997. The K and LS factors were attributes assigned based on the digital soil survey coverage. The C-factors were assigned to land cover files that were derived by supervised remote-sensing techniques. The land-cover classes were visually validated. The P-factor was selected to calibrate the results within physically reasonable soil-loss values and degree of soil conservation practices.

The sediment sample calibration data set was limited due to it short period of record. Using only four events during one water year is hardly representative of the system's variability but it is the best available data at this time.

CONCLUSIONS

Using sediment monitoring and modeling with RUSLE indicated that soil loss has been reduced in the last three decades. Present best management practices are leading to landscape restoration within accepted soil–loss tolerance (T-factors). Average soil-loss estimates are near to tolerance but some "hot spots" still need additional erosion-control efforts. Thus, the recovery trend requires that a stewardship commitment be continued to reverse previous land-use impacts.

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